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The 1st International Conference of Combinatorics, Graph Theory, and Network Topology

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The First International Conference on Combinatorics, Graph Theory and Network Topology (ICCGANT)

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Preface

It is with my great pleasure and honor to organize the First International Conference on Combinatorics, Graph Theory and Network Topology which is held from 25-26 November 2017 in the University of Jember, East Java, Indonesia and present a conference proceeding index by Scopus. It is the first international conference organized by CGANT Research Group University of Jember in cooperation with Indonesian Combinatorics Society (INACOBMS). The conference is held to welcome participants from many countries, with broad and diverse research interests of mathematics especially combinatorical study. The mission is to become an annual international forum in the future, where, civil society organization and representative, research students, academics and researchers, scholars, scientist, teachers and practitioners from all over the world could meet in and exchange an idea to share and to discuss theoretical and practical knowledge about mathematics and its applications. The aim of the first conference is to present and discuss the latest research that contributes to the sharing of new theoretical, methodological and empirical knowledge and a better understanding in the area mathematics, application of mathematics as well as mathematics education.

The themes of this conference are as follows: (1) Connection of distance to other graph properties, (2) Degree/diameter problem, (3) Distance-transitive and distance-regular graphs, (4) Metric dimension and related parameters, (5) Cages and eccentric graphs, (6) Cycles and factors in graphs, (7) Large graphs and digraphs, (8) Spectral Techniques in graph theory, (9) Ramsey numbers, (10) Dimensions of graphs, (11) Communication networks, (12) Coding theory, (13) Cryptography, (14) Rainbow connection, (15) Graph labelings and coloring, (16). Applications of graph theory

The topics are not limited to the above themes but they also include the mathematical application research of interest in general including mathematics education, such as:(1) Applied Mathematics and Modelling, (2) Applied Physics: Mathematical Physics, Biological Physics, Chemistry Physics,(3) Applied Engineering: Mathematical Engineering, Mechanical engineering, Informatics Engineering, Civil Engineering,(4) Statistics and Its Application,(5) Pure Mathematics (Analysis, Algebra and Geometry),(6) Mathematics Education, (7) Literacy of Mathematics,(8) The Use of ICT Based Media In Mathematics Teaching and Learning,(9) Technological, Pedagogical, Content Knowledge for Teaching Mathematics, (10) Students Higher Order Thinking Skill of Mathematics, (11) Contextual Teaching and Realistic Mathematics, (12) Science, Technology, Engineering, and Mathematics Approach, (13) Local Wisdom Based

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Education: Ethnomathematics, (14) Showcase of Teaching and Learning of Mathematics, (16) The 21st Century Skills: The Integration of 4C Skill in Teaching Math.

The participants of this ICCGANT 2017 conference were 200 people consisting research students, academics and researchers, scholars, scientist, teachers and practitioners from many countries. The selected papers to be publish of Journal of Physics: Conference Series are 80 papers. On behalf of the organizing committee, finally we gratefully acknowledge the support from the University of Jember of this conference. We would also like to extend our thanks to all lovely participants who are joining this unforgettable and valuable event.

Prof. Drs. Dafik, M.Sc., Ph.D.

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The Committees of The First International Conference on Combinatorics, Graph Theory and Network Topology (ICCGANT)

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The Committees of The First International Conference on Combinatorics, Graph Theory and Network Topology (ICCGANT)

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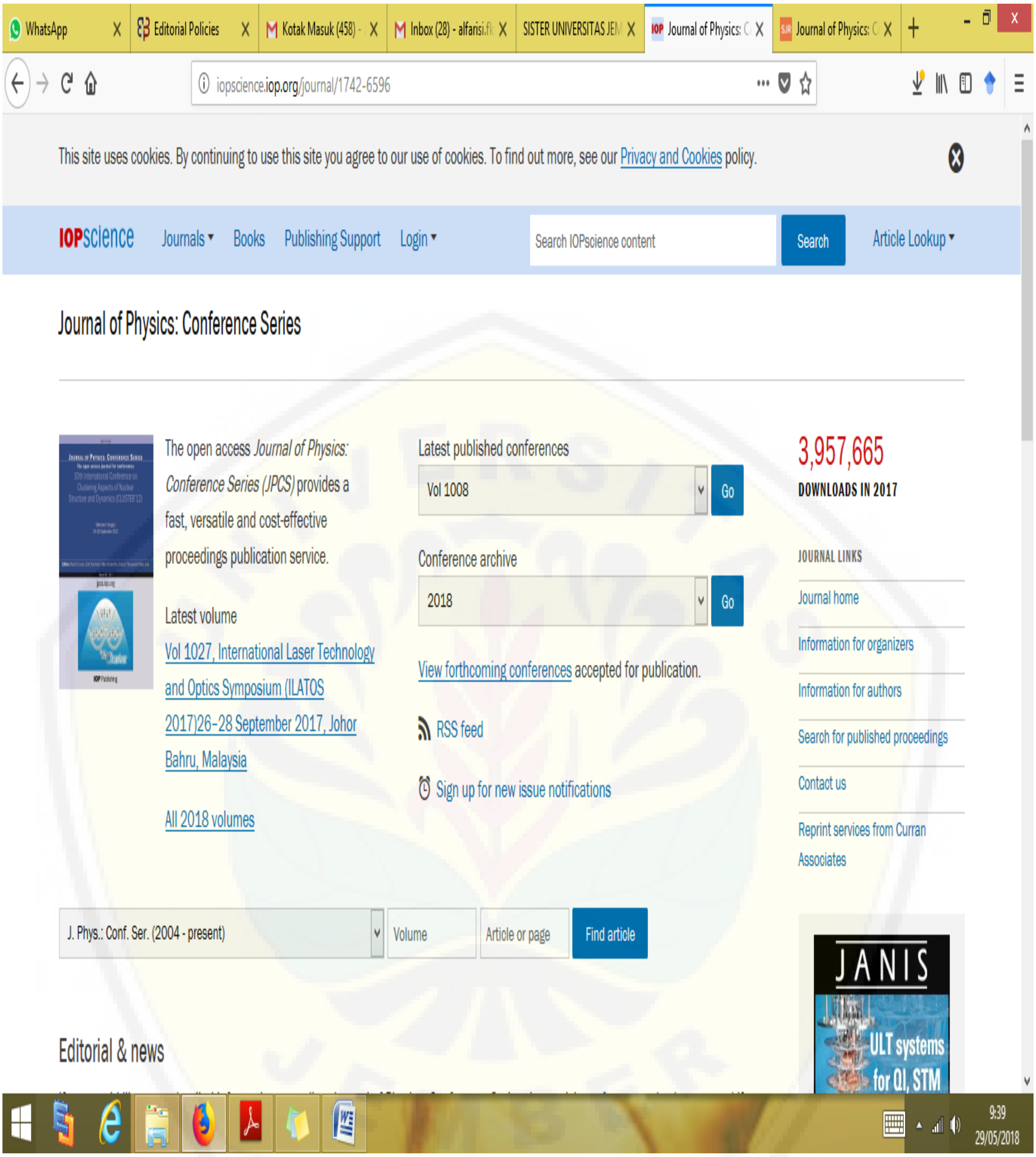
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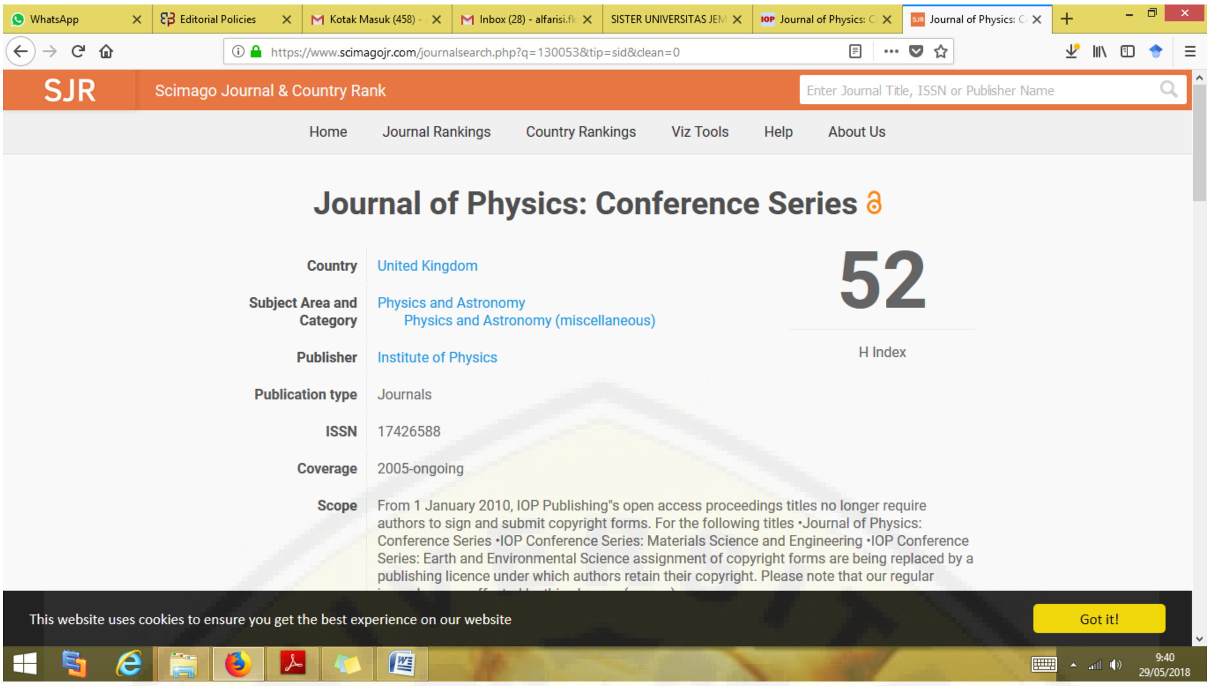
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On the locating domination number of corona product

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On the locating domination number of corona product

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Abstract. Let $G = (V(G), E(G)$ be a connected graph and $v \epsilon V(G)$. A dominating set for a graph $G = (V, E)$ is a subset D of V such that every vertex not in D is adjacent to at least one member of D. The domination number $\gamma(G)$ is the number of vertices in a smallest dominating set for G. Vertex set S in graph $G = (V, E)$ is a locating dominating set if for each pair of distinct vertices u and v in $V(G) - S$ we have $N(u) \cap S \neq \phi$, $N(v) \cap S \neq \phi$, and $N(u) \cap S \neq N(v) \cap S$, that is each vertex outside of S is adjacent to a distinct, nonempty subset of the elements of S. In this paper, we characterize the locating dominating sets in the corona product of graphs namely path, cycle, star, wheel, and fan graph.

Keywords : *Locating dominating sets, dominating sets, locating dominating number, corona product*

1. Introduction

Locating dominating set a natural expansion of dominating set. Historically, dominating set has been studied from the 1960 and developed in the 1970. Foucaud (2016) mention locating dominating set was first introduced and studied by Slater in 1987 [2,3]. Dominating set is a concept of determining a vertex set on a graph, where the vertex that has a condition can dominate the point around it, and the cardinality of members of set should be minimum. Minimum cardinality of the set dominance is called the domination number denoted by γ [1, 4].

According to Haynes and Henning, the set D from vertex of a simple graph G is called dominating set if every vertex $u \in V(G) - D$ adjacent on some vertex $v \in D$ [9,10,11,12]. Let a directed graph not $G = (V, E)$, dominating set is a subset of $S \subseteq V$ of vertex at G, for all vertex $v \in V$ one of $v \in S$ or a neighbor from s ie u is at S [7, 8].

A vertex set of graph $G = (V, E)$ is locating dominating set, if set of vertex dominator denoted by D qualifies that any vertex other than D,that is $V - D$ have different intersection with D. Let V be the vertex and E is the edge set of graph G so $\{u, v \in V \backslash D\}$ then $N(u) \cap D \neq \emptyset$, $N(v) \cap D \neq \emptyset$, and $N(u) \cap D \neq N(v) \cap D$, where $N(u)$ is vertex neighbors of u and $N(v)$ is vertex neighbors of v. Locating dominating number is the minimum cardinality of the locating dominating set. Locating dominating number is denoted by γ_L.

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Some definitions used in this study are :

Definition 1.1 *Let G be a connected graph with $|V(G)| = p_1$ and $|E(G)| = q_1$ the graph H is a connected graph that has $|V(H)| = p_2$ dan $|E(H)| = q_2$. The cardinality of vertex set and edge set at $G \odot H$ respectly are $|V(G \odot H)| = p_1(p_2 + 1)$ and $|E(G \odot H)| = p_1(p_2 + q_2) + q_1$.*

2. Main Result

In this paper, we have studied locating domination number of some corona product. The results of this research, we found several lemma, theorem, and corollary about the locating domination number of corona products.

Lemma 2.1 *Let G and H be a connected graph, the locating domination number of $G \odot H$ is $\gamma_L(G \odot H) \geq |V(G)| \cdot \gamma_L(H)$.*

Proof. The corona products of G and H denoted by $G \odot H$ is a connected graph with the cardinality of vertex set and edge set respectively are $|V(G \odot H)| = |V(G)| \cdot (|V(H)| + 1)$ and $|E(G \odot H)| = |V(G)| \cdot (|V(H)| + |E(H)|) + |E(V)|$.

We prove that the lower bound of locating domination number is $\gamma_L(G \odot H) \geq |V(G)| \cdot \gamma_L(H)$. Based on definition of the corona graph, the graph $G \odot H$ has subgraph H as much as $|V(G)|$. If the vertex dominator on the subgraph H, that is $\gamma_L(H_1) = \gamma_L(H_2) = \gamma_L(H_3) = \ldots = \gamma_L(H_{|V(G)|})$, then $\gamma_L(G \odot H) \geq \gamma_L(H_1) + \gamma_L(H_2) + \gamma_L(H_3) + \ldots + \gamma_L(H_{|V(G)|})$. It concludes that $\gamma_L(G \odot H) \geq |V(G)| \cdot \gamma_L(H)$. □

Theorem 2.2 *For $n \geq 4$, the locating domination number of $G \odot C_n$ is $\gamma_L(G \odot C_n) = |V(G)| \cdot \lceil \frac{2n}{5} \rceil$.*

Proof. Corona products of G and cyle graph C_n denoted by $G \odot C_n$ is a connected graph with the cardinality of vertex set and edge set respectively are $|V(G \odot C_n)| = |V(G)|(n+1)$ and $|E(G \odot C_n)| = n(|V(G)| + |E(G)| + 1)$.

Based on Lemma 2.1, lower bound of locating domination number $G \odot C_n$ is $\gamma_L(G \odot C_n) \geq |V(G)| \cdot \lceil \frac{2n}{5} \rceil$. However we can attain sharpest lower bound. Forthemore, we prove the upper bound of locating domination number is $\gamma_L(G \odot C_n) \leq |V(G)| \cdot \lceil \frac{2n}{5} \rceil$. We determine vertex dominator of $G \odot C_n$ on the subgraph C_n, that is $D = \{x_{ij}; 1 \leq i \leq |V(G)|; 1 \leq j \leq \lceil \frac{2n}{5} \rceil\}$, so $|D| = |V(G)| \cdot \lceil \frac{2n}{5} \rceil$. The neighbors of $V - D = \{x_i, x_{ij}; 1 \leq i \leq |V(G)|; 1 \leq j \leq n - \lceil \frac{2n}{5} \rceil\}$ has different intersection sets with D, it is $N(x_{i(5k)}) \cap D = \{x_{i(5k-1)}, x_{i(5k+1)}\}, N(x_{i(5k-2)}) \cap D = \{x_{i(5k-1)}\}, N(x_{i(5k-3)}) \cap D = \{x_{i(5k-4)}\}, N(x_i) \cap D = \{x_{ij}; j \equiv 1 \; mod 5; j \equiv 4 \; mod 5\}$.

It is easy to see that $\gamma_(G \odot C_n)$ meet $\gamma_(G \odot C_n) \leq |V(G)| \cdot \lceil \frac{2n}{5} \rceil$. Therefore upper bound is $\gamma_(G \odot C_n) \leq |V(G)| \cdot \lceil \frac{2n}{5} \rceil$. It concludes that $\gamma_(G \odot C_n) = |V(G)| \cdot \lceil \frac{2n}{5} \rceil$. □

For the illustration of the locating domination number of $G \odot C_4$ can be seen in Figure 1, we mark the vertex is the vertex dominator of locating dominating set. $G \odot C_4$ has vertex dominator $D = \{x_{ij}; 1 \leq i \leq |V(G)|; 1 \leq j \leq n\}$ is that $D = \{x_{12}, x_{13}, x_{22}, x_{23}, \ldots, x_{|V(G)|2}, x_{|V(G)|3}\}$ and another vertex which is not vertex dominator $(V - D) = \{x_{11}, x_{14}, x_{21}, x_{24}, \ldots, x_{p_1 1}, x_{p_1 4}, x_1, x_2, x_3, \ldots, x_{|V(G)|}\}$ has different neighbors in D, that is $N(x_{11}) \cap D = \{x_{12}\}, N(x_{14}) \cap D = \{x_{13}\}, N(x_{21}) \cap D = \{x_{22}\}, N(x_{21}) \cap D = \{x_{22}\}, N(x_{24}) \cap D = \{x_{23}\}, \ldots, N(x_{p_1 1}) \cap D = \{x_{|V(G)|2}\}, N(x_{|V(G)|4}) \cap D = \{x_{|V(G)|3}\}, N(x_1) \cap D = \{x_{12}, x_{13}\}, N(x_2) \cap D = \{x_{22}, x_{23}\}, \ldots, N(x_{|V(G)|}) \cap D = \{x_{|V(G)|2}, x_{|V(G)|3}\}$. It is easy to see $N(u, v) \cap D \neq \emptyset$ and $N(u) \cap D \neq N(v) \cap D$. It is concludes that $\gamma_L(G \odot C_4) = 2|V(G)|$.

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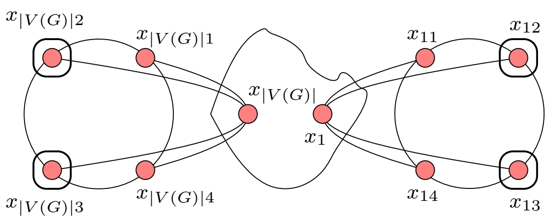

$G \odot C_4$

Figure 1. Locating domination number of $G \odot C_4$ is $2 \cdot |V(G)|$

The corollary of theorem :

Corollary 2.3 *For $n \geq 3$ and $m \geq 4$, the locating domination number of $P_n \odot C_m$ is* $\gamma_L(P_n \odot C_m) = n \cdot \lceil \frac{2m}{5} \rceil$.

Corollary 2.4 *For $n \geq 3$ and $m \geq 4$, the locating domination number of $C_n \odot C_m$ is* $\gamma_L(C_n \odot C_m) = n \cdot \lceil \frac{2m}{5} \rceil$.

Corollary 2.5 *For $n \geq 3$ and $m \geq 4$, the locating domination number of $S_n \odot C_m$ is* $\gamma_L(S_n \odot C_m) = (n+1) \cdot \lceil \frac{2m}{5} \rceil$.

Corollary 2.6 *For $n \geq 3$ and $m \geq 4$, the locating domination number of $W_n \odot C_m$ is* $\gamma_L(W_n \odot C_m) = (n+1) \cdot \lceil \frac{2m}{5} \rceil$.

Corollary 2.7 *For $n \geq 3$ and $m \geq 4$, the locating domination number of $F_n \odot C_m$ is* $\gamma_L(F_n \odot C_m) = (n+1) \cdot \lceil \frac{2m}{5} \rceil$.

Theorem 2.8 *For $n \geq 3$, the locating domination number of $G \odot P_n$ is $\gamma_L(G \odot P_n) = |V(G)| \cdot \lceil \frac{2n}{5} \rceil$.*

Proof. Corona products of G and path graph P_n denoted by $G \odot P_n$ is a connected graph with the cardinality of vertex set and edge set respectively are $|V(G \odot P_n)| = |V(G)|(n+1)$ and $|E(G \odot P_n)| = n(|V(G)| + |E(G)| + 1)$.

Based on Lemma 2.1, lower bound of locating domination number $G \odot P_n$ is $\gamma_L(G \odot P_n) \geq |V(G)| \cdot \lceil \frac{2n}{5} \rceil$. However we can attain sharpest lower bound. Forthemore, we prove the upper bound of locating domination number is $\gamma_L(G \odot P_n) \leq |V(G)| \cdot \lceil \frac{2n}{5} \rceil$. We determine vertex dominator of $G \odot P_n$ on the subgraph P_n, that is $D = \{x_{ij}; 1 \leq i \leq |V(G)|; 1 \leq j \leq \lceil \frac{2n}{5} \rceil\}$, so $|D| = |V(G)| \cdot \lceil \frac{2n}{5} \rceil$. The next, we will show that the neighbors of $V - D = \{x_i, x_{ij}; 1 \leq i \leq |V(G)|; 1 \leq j \leq n - \lceil \frac{2n}{5} \rceil\}$ has different intersection sets with D, it is $N(x_{i(5k)}) \cap D = \{x_{i(5k-1)}, x_{i(5k+1)}\}, N(x_{i(5k-2)}) \cap D = \{x_{i(5k-1)}\}, N(x_{i(5k-3)}) \cap D = \{x_{i(5k-4)}\}, N(x_i) \cap D = \{x_{ij}; j \equiv 1\ mod 5; j \equiv 4\ mod 5\}$.

It is easy to see that $\gamma_(G \odot P_n)$ meet $\gamma_(G \odot P_n) \leq |V(G)| \cdot \lceil \frac{2n}{5} \rceil$. Therefore upper bound is $\gamma_(G \odot P_n) \leq |V(G)| \cdot \lceil \frac{2n}{5} \rceil$. It concludes that $\gamma_(G \odot P_n) = |V(G)| \cdot \lceil \frac{2n}{5} \rceil$. □

For the illustration of the locating domination number of $G \odot P_4$ can be seen in Figure 2, we mark the vertex is the vertex dominator of locating dominating set. $G \odot P_4$ has vertex dominator $D = \{x_{ij}; 1 \leq i \leq |V(G)|; 1 \leq j \leq n\}$ is that $D = \{x_{12}, x_{13}, x_{22}, x_{23}, \ldots, x_{|V(G)|2}, x_{|V(G)|3}\}$ and another vertex which is not vertex dominator $(V - D) = \{x_{11}, x_{14}, x_{21}, x_{24}, \ldots, x_{p1}, x_{p4}, x_1, x_2, x_3, \ldots, x_{|V(G)|}\}$ has different neighbors in D, that is $N(x_{11}) \cap D = \{x_{12}\}, N(x_{14}) \cap D = \{x_{13}\}, N(x_{21}) \cap D = \{x_{22}\}, N(x_{21}) \cap D = \{x_{22}\}, N(x_{24}) \cap D = \{x_{23}\}, \ldots, N(x_{p1}) \cap D = \{x_{|V(G)|2}\}, N(x_{|V(G)|4}) \cap D = \{x_{|V(G)|3}\}, N(x_1) \cap$

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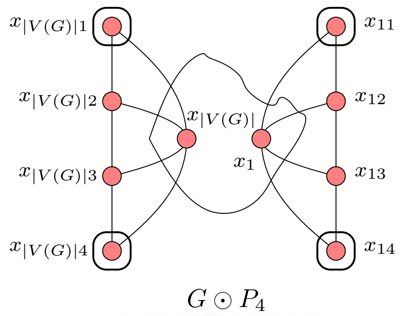

Figure 2. Locating domination number of $G \odot P_4$ is $2 \cdot |V(G)|$

$D = \{x_{12}, x_{13}\}, N(x_2) \cap D = \{x_{22}, x_{23}\}, \ldots, N(x_{|V(G)|}) \cap D = \{x_{|V(G)|2}, x_{|V(G)|3}\}$. It is easy to see $N(u,v) \cap D \neq \emptyset$ and $N(u) \cap D \neq N(v) \cap D$. It is concludes that $\gamma_L(G \odot P_4) = 2|V(G)|$.

The corollary of theorem :

Corollary 2.9 *For $n \geq 3$ and $m \geq 4$, the locating domination number of $P_n \odot P_m$ is $\gamma_L(P_n \odot P_m) = n \cdot \lceil \frac{2m}{5} \rceil$.*

Corollary 2.10 *For $n \geq 3$ and $m \geq 4$, the locating domination number of $C_n \odot P_m$ is $\gamma_L(C_n \odot P_m) = n \cdot \lceil \frac{2m}{5} \rceil$.*

Corollary 2.11 *For $n \geq 3$ and $m \geq 4$, the locating domination number of $S_n \odot P_m$ is $\gamma_L(S_n \odot P_m) = (n+1) \cdot \lceil \frac{2m}{5} \rceil$.*

Corollary 2.12 *For $n \geq 3$ and $m \geq 4$, the locating domination number of $W_n \odot P_m$. is $\gamma_L(W_n \odot P_m) = (n+1) \cdot \lceil \frac{2m}{5} \rceil$.*

Corollary 2.13 *For $n \geq 3$ and $m \geq 4$, the locating domination number of $F_n \odot P_m$ is $\gamma_L(F_n \odot P_m) = (n+1) \cdot \lceil \frac{2m}{5} \rceil$.*

Lemma 2.14 *Let G and H be a connected graph, the locating domination number of $G \odot H$ is $\gamma_L(G \odot H) \leq \gamma(G) + |V(G)| \cdot \gamma_L(H)$.*

Proof. The corona products of G and H denoted by $G \odot H$ is a connected graph with the cardinality of vertex set and edge set respectively are $|V(G \odot H)| = |V(G)| \cdot (|V(H)| + 1)$ and edge's cardinality $|E(G \odot H)| = |V(G)| \cdot (|V(H)| + |E(H)|) + |E(V)|$.

We prove that the upper bound of locating domination number is $\gamma_L(G \odot H) \leq \gamma(G) + |V(G)| \cdot \gamma_L(H)$. Based on definition of the corona graph, every $G \odot H$ has subgraph H as much as $|V(G)|$. If the vertex dominator on the subgraph G that is $\gamma(G)$ and on the subgraph H that is $\gamma_L(H_1) = \gamma_L(H_2) = \gamma_L(H_3) = \ldots = \gamma_L(H_{|V(G)|})$, then $\gamma_L(G \odot H) \geq \gamma_L(H_1) + \gamma_L(H_2) + \gamma_L(H_3) + \ldots + \gamma_L(H_{|V(G)|} + \gamma(G))$. It concludes that $\gamma_L(G \odot H) \leq \gamma(G) + |V(G)| \cdot \gamma_L(H)$. □

Theorem 2.15 *For $n \geq 4$, the locating domination number of $G \odot S_n$ is $\gamma_L(G \odot S_n) = \gamma(G) + |V(G)| \cdot n$.*

Proof. Corona products of G and path graph S_n denoted by $G \odot S_n$ is a connected graph with the cardinality of vertex set and edge set respectively are $|V(G \odot S_n)| = |V(G)| \cdot (n+2)$ and $|E(G \odot S_n)| = |V(G)| \cdot (2n+1) + |E(G)|$.

Based on Lemma 2.2, upper bound of locating domination number $G \odot S_n$ is $\gamma_L(G \odot S_n) \geq \gamma(G) + |V(G)| \cdot n$. However we can attain sharpest lower bound. Forthemore, we prove the lower bound of locating domination number is $\gamma_L(G \odot S_n) \geq \gamma(G) + |V(G)| \cdot n$. We determine set of vertex dominator of $G \odot S_n$ on the subgraph G, that is $D = \{x_i; 1 \leq i \leq \gamma(G)\}$ and on the subgraph S_n, that is $D = \{x_{ij}; 1 \leq i \leq |V(G)|; 1 \leq j \leq n\}$ so $|D| = \gamma(G) + |V(G)| \cdot n$. The next, we will show that the neighbors of $V - D = \{x_i, x_{ij}; 1 \leq i \leq |V(G)|; j = n+1\}$ has different intersection sets with D, it is $N(x_{i(n+1)}) \cap D = \{x_{i1}, x_{i2}, \ldots, x_{in}; 1 \leq i \leq n\}, N(x_i) \cap D = \{x_{i1}, x_{i2}, \ldots, x_{in}, \gamma(G); 1 \leq i \leq n\}$.

It is easy to see that $\gamma_(G \odot S_n)$ meet $\gamma_L(G \odot S_n) \geq \gamma(G) + |V(G)| \cdot n$. Therefore lower bound is $\gamma_L(G \odot S_n) \geq \gamma(G) + |V(G)| \cdot n$. It concludes that $\gamma_L(G \odot S_n) = \gamma(G) + |V(G)| \cdot n$. $\square$

For the illustration of the locating domination number of $G \odot S_4$ can be seen in Figure 3, we mark the vertex is the vertex dominator of locating dominating set. $G \odot S_4$ has vertex dominator $D = \{x_i; x_{ij}; 1 \leq i \leq |V(G)|; 1 \leq j \leq n\}$ is that $D = \{x_{11}, x_{12}, x_{13}, x_{14}, x_{21}, x_{12}, x_{23}, x_{24}, \ldots, x_{p_1 1}, x_{p_1 2}, x_{p_1 3}, x_{p_1 4}\}$ and another vertex which is not vertex dominator $(V - D) = \{x_{15}, x_{25}, \ldots, x_{p_1 5}, \gamma(G)\}$ has different neighbors in D, that is $N(x_{15}) \cap D = \{x_{11}, x_{12}, x_{13}, x_{14}\}, N(x_{25}) \cap D = \{x_{21}, x_{22}, x_{23}, x_{24}\}, \ldots, N(x_{p_1 5}) \cap D = \{x_{p_1 1}, x_{p_1 2}, x_{p_1 3}, x_{p_1 4}\}, N(x_1) \cap D = \{x_{11}, x_{12}, x_{13}, x_{14}, \gamma(G)\}, N(x_2) \cap D = \{x_{21}, x_{22}, x_{23}, x_{24}, \gamma(G)\}, \ldots, N(x_{p_1}) \cap D = \{x_{p_1 1}, x_{p_1 2}, x_{p_1 3}, x_{p_1 4}, \gamma(G)\}$. It is easy to see $N(u, v) \cap D \neq \emptyset$ and $N(u) \cap D \neq N(v) \cap D$. It is concludes that $\gamma_L(G \odot S_4) = \gamma(G) + 4|V(G)|$.

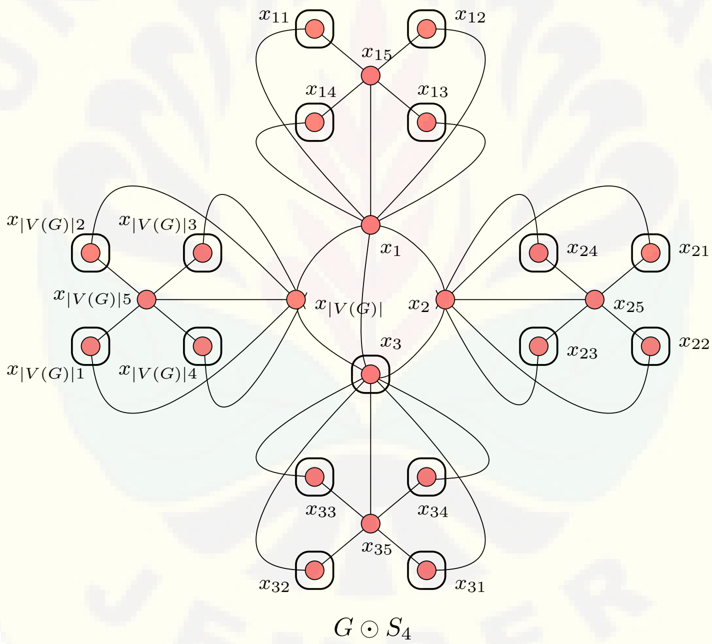

Figure 3. Locating domination number of $G \odot S_4$ is $\gamma(G) + 4 \cdot |V(G)|$

The corollary of theorem :

Corollary 2.16 *For $n \geq 3$ and $m \geq 4$, the locating domination number of $P_n \odot S_m$ is $\gamma_L(P_n \odot S_m) = \gamma(G) + n \cdot m$.*

Corollary 2.17 *For $n \geq 3$ and $m \geq 4$, the locating domination number of $C_n \odot S_m$ is $\gamma_L(C_n \odot S_m) = \gamma(G) + n \cdot m$.*

Corollary 2.18 *For $n \geq 3$ and $m \geq 4$, the locating domination number of $S_n \odot S_m$ is $\gamma_L(S_n \odot S_m) = \gamma(G) + (n+1) \cdot m$.*

Corollary 2.19 *For $n \geq 3$ and $m \geq 4$, the locating domination number of $W_n \odot S_m$ is $\gamma_L(W_n \odot S_m) = \gamma(G) + (n+1) \cdot m$.*

Corollary 2.20 *For $n \geq 3$ and $m \geq 4$, the locating domination number of $F_n \odot S_m$ is $\gamma_L(F_n \odot S_m) = \gamma(G) + (n+1) \cdot m$.*

Theorem 2.21 *For $n \geq 4$, the locating domination number of $G \odot W_n$ is $\gamma_L(G \odot W_n) = \gamma(G) + |V(G)| \cdot \lceil \frac{2n}{5} \rceil$.*

Proof. Corona products of G and path graph W_n denoted by $G \odot W_n$ is a connected graph with the cardinality of vertex set and edge set respectively are $|V(G \odot W_n)| = p_1(n+2)$ and $|E(G \odot W_n)| = 3np_1 + q_1$.

Based on Lemma 2.2, upper bound of locating domination number $G \odot W_n$ is $\gamma_L(G \odot W_n) \geq \gamma(G) + |V(G)| \cdot \lceil \frac{2n}{5} \rceil$. However we can attain sharpest lower bound. Forthemore, we prove the lower bound of locating domination number is $\gamma_L(G \odot W_n) \geq \gamma(G) + |V(G)| \cdot \lceil \frac{2n}{5} \rceil$. We determine set of vertex dominator of $G \odot S_n$ on the subgraph G, that is $D = \{x_i; 1 \leq i \leq \gamma(G)\}$ and on the subgraph S_n, that is $D = \{x_{ij}; 1 \leq i \leq |V(G)|; 1 \leq j \leq \lceil \frac{2n}{5} \rceil\}$ so $|D| = \gamma(G) + |V(G)| \cdot \lceil \frac{2n}{5} \rceil$. The next, we will show that the neighbors of $V - D = \{x_i, x_{ij}; 1 \leq i \leq |V(G)|; 1 \leq j \leq (n+1) - \lceil \frac{2n}{5} \rceil\}$ has different intersection sets with D, it is $N(x_{i(5k)}) \cap D = \{x_{i(5k-1)}, x_{i(5k+1)}\}, N(x_{i(5k-2)}) \cap D = \{x_{i(5k-1)}\}, N(x_{i(5k-3)}) \cap D = \{x_{i(5k-4)}\}, N(x_{i(n+1)}) \cap D = \{x_{i(5k-4)}, x_{i(5k-1)}; 1 \leq k \leq \lceil n \rceil\}, N(x_i) \cap D = \{x_{ij}, \gamma(G); j \equiv 1 \ mod 5; j \equiv 4 \ mod 5\}$.

It is easy to see that $\gamma_(G \odot W_n)$ meet $\gamma_L(G \odot W_n) \geq \gamma(G) + |V(G)| \cdot \lceil \frac{2n}{5} \rceil$. Therefore lower bound is $\gamma_L(G \odot W_n) \geq \gamma(G) + |V(G)| \cdot \lceil \frac{2n}{5} \rceil$. It concludes that $\gamma_L(G \odot W_n) = \gamma(G) + |V(G)| \cdot \lceil \frac{2n}{5} \rceil$. □

For the illustration of the locating domination number of $G \odot W_4$ can be seen in Figure 4, we mark the vertex is the vertex dominator of locating dominating set. $G \odot W_4$ has vertex dominator $D = \{x_i; x_{ij}; 1 \leq i \leq |V(G)|; 1 \leq j \leq n\}$ is that $D = \{x_{11}, x_{14}, x_{21}, x_{24}, \ldots, x_{|V(G)|1}, x_{|V(G)|4}\}$ and another vertex which is not vertex dominator $(V - D) = \{x_{12}, x_{13}, x_{15}, x_{22}, x_{23}, x_{25}, \ldots, x_{|V(G)|2}, x_{|V(G)|3}, x_{|V(G)|5}, x_1, x_2, x_3, \ldots, x_{|V(G)|}\}$ has different neighbors in D, that is $N(x_{12}) \cap D = \{x_{11}\}, N(x_{13}) \cap D = \{x_{14}\}, N(x_{15}) \cap D = \{x_{11}, x_{14}\}, N(x_{22}) \cap D = \{x_{21}\}, N(x_{23}) \cap D = \{x_{24}\}, N(x_{25}) \cap D = \{x_{21}, x_{24}\}, \ldots, N(x_{|V(G)|2}) \cap D = \{x_{|V(G)|1}\}, N(x_{|V(G)|3}) \cap D = \{x_{|V(G)|4}\}, N(x_{|V(G)|5}) \cap D = \{x_{|V(G)|1}, x_{|V(G)|4}\}, N(x_1) \cap D = \{x_{11}, x_{14}, \gamma(G)\}, N(x_2) \cap D = \{x_{21}, x_{24}, \gamma(G)\}, \ldots, N(x_{|V(G)|}) \cap D = \{x_{|V(G)|1}, x_{|V(G)|4}, \gamma(G)\}$. It is easy to see $N(u,v) \cap D \neq \emptyset$ and $N(u) \cap D \neq N(v) \cap D$. It is concludes that $\gamma_L(G \odot W_4) = \gamma(G) + 2|V(G)|$.

The corollary of theorem :

Corollary 2.22 *For $n \geq 3$ and $m \geq 4$, the locating domination number of $P_n \odot W_m$ is $\gamma_L(P_n \odot W_m) = \gamma(G) + n \cdot \lceil \frac{2m}{5} \rceil$.*

Corollary 2.23 *For $n \geq 3$ and $m \geq 4$, the locating domination number of $C_n \odot W_m$ is $\gamma_L(C_n \odot W_m) = \gamma(G) + n \cdot \lceil \frac{2m}{5} \rceil$.*

Corollary 2.24 *For $n \geq 3$ and $m \geq 4$, the locating domination number of $S_n \odot W_m$ is $\gamma_L(S_n \odot W_m) = \gamma(G) + (n+1) \cdot \lceil \frac{2m}{5} \rceil$.*

Corollary 2.25 *For $n \geq 3$ and $m \geq 4$, the locating domination number of $W_n \odot W_m$. is $\gamma_L(W_n \odot W_m) = \gamma(G) + (n+1) \cdot \lceil \frac{2m}{5} \rceil$.*

Corollary 2.26 *For $n \geq 3$ and $m \geq 4$, the locating domination number of $F_n \odot W_m$ is $\gamma_L(F_n \odot W_m) = \gamma(G) + (n+1) \cdot \lceil \frac{2m}{5} \rceil$.*

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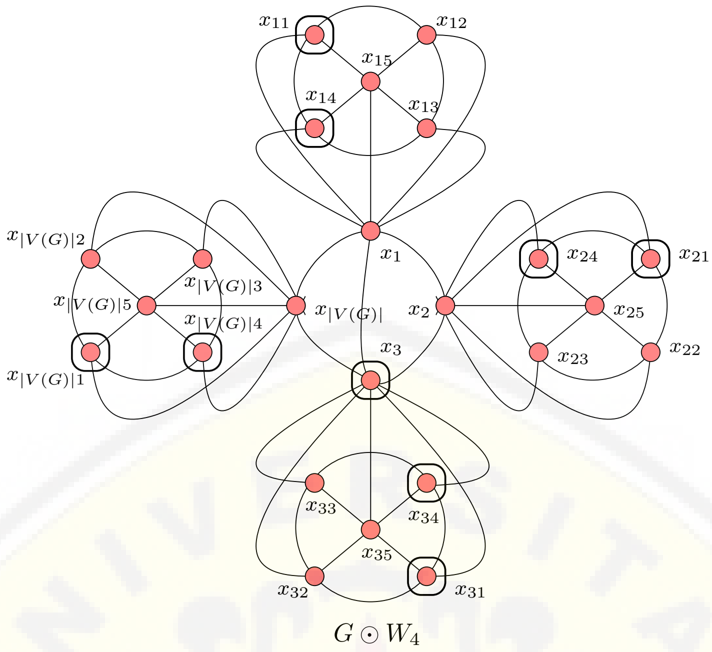

Figure 4. Locating domination number of $G \odot W_4$ is $\gamma(G) + 2 \cdot |V(G)|$

Theorem 2.27 *For $n \geq 4$, the locating domination number of $G \odot F_n$ is $\gamma_L(G \odot F_n) = \gamma(G) + |V(G)| \cdot \lceil \frac{2n}{5} \rceil$.*

Proof. Corona products of G and path graph F_n denoted by $G \odot F_n$ is a connected graph with the cardinality of vertex set and edge set respectively are $|V(G \odot F_n)| = p_1(n+2)$ and $|E(G \odot F_n)| = 2np_1 + q_1$.

Based on Lemma 2.2, upper bound of locating domination number $G \odot W_n$ is $\gamma_L(G \odot F_n) \geq \gamma(G) + |V(G)| \cdot \lceil \frac{2n}{5} \rceil$. However we can attain sharpest lower bound. Forthemore, we prove the lower bound of locating domination number is $\gamma_L(G \odot F_n) \geq \gamma(G) + |V(G)| \cdot \lceil \frac{2n}{5} \rceil$. We determine vertex dominator of $G \odot F_n$ on the subgraph G, that is $D = \{x_i; 1 \leq i \leq \gamma(G)\}$ and on the subgraph F_n, that is $D = \{x_{ij}; 1 \leq i \leq |V(G)|; 1 \leq j \leq \lceil \frac{2n}{5} \rceil\}$ so $|D| = \gamma(G) + |V(G)| \cdot \lceil \frac{2n}{5} \rceil$. The next, we will show that the neighbors of $V - D = \{x_i, x_{ij}; 1 \leq i \leq |V(G)|; 1 \leq j \leq (n+1) - \lceil \frac{2n}{5} \rceil\}$ has different intersection sets with D, it is $N(x_{i(5k)}) \cap D = \{x_{i(5k-1)}, x_{i(5k+1)}\}, N(x_{i(5k-2)}) \cap D = \{x_{i(5k-1)}\}, N(x_{i(5k-3)}) \cap D = \{x_{i(5k-4)}\}, N(x_{i(n+1)}) \cap D = \{x_{i(5k-4)}, x_{i(5k-1)}; 1 \leq k \leq \lceil n \rceil\}, N(x_i) \cap D = \{x_{ij}, \gamma(G); j \equiv 1\ mod5; j \equiv 4\ mod5\}$.

It is easy to see that $\gamma_(G \odot F_n)$ meet $\gamma_L(G \odot F_n) \geq \gamma(G) + |V(G)| \cdot \lceil \frac{2n}{5} \rceil$. Therefore lower bound is $\gamma_L(G \odot F_n) \geq \gamma(G) + |V(G)| \cdot \lceil \frac{2n}{5} \rceil$. It concludes that $\gamma_L(G \odot F_n) = \gamma(G) + |V(G)| \cdot \lceil \frac{2n}{5} \rceil$. □

For the illustration of the locating domination number of $G \odot F_4$ can be seen in Figure 5, we mark the vertex is the vertex dominator of locating dominating set. $G \odot F_4$ has vertex dominator $D = \{x_i; x_{ij}; 1 \leq i \leq |V(G)|; 1 \leq j \leq n\}$ is that $D = \{x_{11}, x_{14}, x_{21}, x_{24}, \dots, x_{|V(G)|1}, x_{|V(G)|4}\}$ and another vertex which is not vertex dominator $(V - D) = \{x_{12}, x_{13}, x_{15}, x_{22}, x_{23}, x_{25}, \dots, x_{|V(G)|2}, x_{|V(G)|3}, x_{|V(G)|5}, x_1, x_2, x_3, \dots, x_{|V(G)|}\}$ has different neighbors in D, that is $N(x_{12}) \cap D = \{x_{11}\}, N(x_{13}) \cap D = \{x_{14}\}, N(x_{15}) \cap D = \{x_{11}, x_{14}\}, N(x_{22}) \cap D = \{x_{21}\}, N(x_{23}) \cap D = \{x_{24}\}, N(x_{25}) \cap D = \{x_{21}, x_{24}\}, \dots, N(x_{|V(G)|2}) \cap D = \{x_{|V(G)|1}\}, N(x_{|V(G)|3}) \cap D = \{x_{|V(G)|4}\}, N(x_{|V(G)|5}) \cap D = \{x_{|V(G)|1}, x_{|V(G)|4}\}, N(x_1) \cap D =$

$\{x_{11}, x_{14}, \gamma(G)\}, N(x_2) \cap D = \{x_{21}, x_{24}, \gamma(G)\}, \ldots, N(x_{|V(G)|}) \cap D = \{x_{|V(G)|1}, x_{|V(G)|4}, \gamma(G)\}$. It is easy to see $N(u, v) \cap D \neq \emptyset$ and $N(u) \cap D \neq N(v) \cap D$. It is concludes that $\gamma_L(G \odot F_4) = \gamma(G) + 2|V(G)|$.

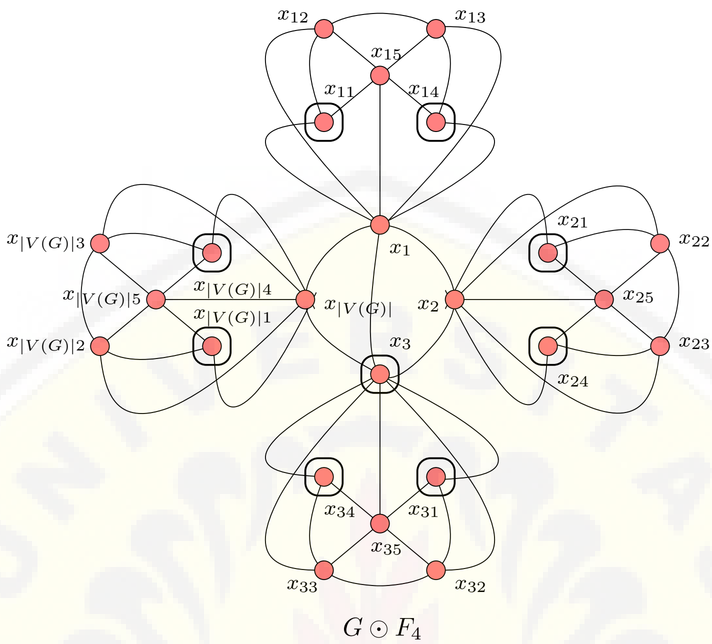

Figure 5. Locating domination number of $G \odot F_4$ is $\gamma(G) + 2 \cdot |V(G)|$

The corollary of theorem :

Corollary 2.28 *For $n \geq 3$ and $m \geq 4$, the locating domination number of $P_n \odot F_m$ is* $\gamma_L(P_n \odot F_m) = \gamma(G) + n \cdot \lceil \frac{2m}{5} \rceil$.

Corollary 2.29 *For $n \geq 3$ and $m \geq 4$, the locating domination number of $C_n \odot F_m$ is* $\gamma_L(C_n \odot F_m) = \gamma(G) + n \cdot \lceil \frac{2m}{5} \rceil$.

Corollary 2.30 *For $n \geq 3$ and $m \geq 4$, the locating domination number of $S_n \odot F_m$ is* $\gamma_L(S_n \odot F_m) = \gamma(G) + (n+1) \cdot \lceil \frac{2m}{5} \rceil$.

Corollary 2.31 *For $n \geq 3$ and $m \geq 4$, the locating domination number of $W_n \odot F_m$. is* $\gamma_L(W_n \odot F_m) = \gamma(G) + (n+1) \cdot \lceil \frac{2m}{5} \rceil$.

Corollary 2.32 *For $n \geq 3$ and $m \geq 4$, the locating domination number of $F_n \odot F_m$ is* $\gamma_L(F_n \odot F_m) = \gamma(G) + (n+1) \cdot \lceil \frac{2m}{5} \rceil$.

3. Conclusion

Based on the results of the above research, then we can conclude the locating domination number of $G \odot H$ is $\gamma_L(G \odot H) \geq |V(G)| \cdot \gamma_L(H)$ and $G \odot H$ is $\gamma_L(G \odot H) \leq \gamma(G) + |V(G)| \cdot \gamma_L(H)$.

Open Problem 3.1. *Define the locating domination number of the other operations graph*

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